ANALYSIS AND OBSERVATION OF GRID CONNECTED SINGLE PHASE INVERTER INTEGRATION

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Specially dedicated to my beloved mother and father

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In the name of Allah, The beneficent the merciful. All praises and glory are to Almighty Allah, the lord of the world. May the peace and blessings of Allah be to our noble prophet Mohammed (SAW), his family, his companions and the generality of believers who sincerely believes in his message till the day of judgment (amen).

Since the Prophet MOHAMMED "Peace be upon him" said: "Whoever does not thank people (For their favors) has not thanked Allah (properly), therefore, first, to my heartfelt thanks goes to my parents, I cannot have enough words to express my thanks to both of you. Thank you for being my wonderful parents. Without you both, I would not have been to where I am today.

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ABSTRACT

A single-phase grid connected with a photovoltaic (PV) power system that will provide high voltage gain with state model analysis for the control of the system has been presented. In addition to the solar panels, the system is equipped with a dc–dc converter, which allows the panels' maximum power point to be tracked, a single-phase inverter and PI controller, all connected to a single-phase utility grid. The maximum power point is maintained with a perturb and observe method. A PI controller is used to control the power injected into the grid. The controller is used to generate PWM and also controlling extra power. The maximum power delivered, and it is synchronized with help of PWM to improve the power quality and system efficiency. In this project the design separated in closed loop and open loop designs. The result in both designs are different where is the voltage will be increase up to 3.214% more in closed loop design. Also, the power will increase up to 27.78% in closed loop design.

ABSTRAK

Satu grid fasa tunggal yang berkaitan dengan sistem kuasa photovoltaic (PV) yang akan memberikan keuntungan voltan tinggi dengan analisis model keadaan untuk kawalan sistem telah dibentangkan. Sebagai tambahan kepada panel solar, sistem ini dilengkapi dengan penukar dc-dc, yang membolehkan titik kuasa maksimum panel dikesan, inverter fasa tunggal dan pengawal PI, semuanya disambungkan ke grid utiliti fasa tunggal. Titik kuasa maksimum dikekalkan dengan kaedah perturb dan memerhati. Pengawal PI digunakan untuk mengawal kuasa disuntik ke grid. Pengawal digunakan untuk menghasilkan PWM dan juga mengawal kuasa tambahan. Kuasa maksimum dihantar, dan ia disegerakkan dengan bantuan PWM untuk meningkatkan kualiti tenaga dan kecekapan sistem. Dalam projek ini reka bentuk dipisahkan dalam gelung tertutup dan reka bentuk gelung terbuka. Hasilnya dalam kedua-dua reka bentuk adalah berbeza di mana voltan akan meningkat sehingga 3.214% lebih daripada reka bentuk gelung terbuka. Juga, kuasa akan meningkat sehingga 27.78% dalam reka bentuk gelung tertutup.

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LIST OF SYMBOLS AND ABBREVIATIONS

PV	-	Photovoltaic
PI	-	Proportional integral
MPPT	-	Maximum power point tracking
P&O	-	Perturb and observe
PLL	-	Synchronous Reference frame

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CHAPTER 1

INTRODUCTION

1.1 Overview

Renewable sources of energy such as biomass, wave energy, wind power, hydroelectricity, and solar power could be alternative sources to replace fossil energy sources [1]. Grid-connected PV systems are a popular and well-established technology due to their contributions to clean energy generation. The aim of this technology is to extract the maximum possible energy out of PV modules by tracking its MPP, injecting a high-quality current into the grid and enhancing the overall efficiency of the PV system. The relatively high cost of PV modules has led researchers to focus on cheap and innovative inverter topologies to make PV power generation more attractive. This, in turn, has resulted in a high diversity of inverter topologies and system configurations. However, the most common topology for single-phase grid connected systems is the two-level multi-string inverter. In this topology, several dc-dc converters, each of which is connected to a PV array, share a single dc-link as an output. This topology offers several advantages such as: easy expansion of the system .

Power by adding more dc-dc converters and PV modules, independent MPP tracking for each PV array and simple control schemes. In the past decade, multilevel inverter topologies have been introduced to PV applications [2]. These topologies can inject a high-quality current with a low harmonic distortion to the grid, reach higher efficiencies with low switching frequency techniques and eliminate the bulky line-side filter and transformer that are required in the integration of PV systems to a high voltage grid. Besides, multilevel topologies feature several dc-links which can be used to lessen the effects of module mismatches in PV arrays. Among the different types of multilevel converters [3].

The single-stage grid-connected PV system has only a stage of power conversion, which has many advantages including simple circuit topology, high efficiency, and low lost. However, the maximum power point tracking (MPPT) of the PV array, the demand for the output power factor, and the suppression of harmonic wave have to been realized in one stage of power conversion [3]. Thus, that results in the complex control. Buck inverter is often used in the single-stage grid-connected PV system. A drawback of which is required that the PV array operating voltage is greater than the grid voltage amplitude. To overcome the drawback, the output set- up transformer is often connected between the buck inverter output and the grid. Which result in the reduced efficiency and the bulky volume [4].

1.2 Problem Statement

One of the principal problems of a grid-connected inverter operating with renewable energy sources is the variable power that the generator produces. that signal will not be stable, less efficiency and the system performance reduced. So, in this project trying to solve all of these issues and make the system stable. In this mode of solar power generation, the solar arrays are used in large capacities, which are coupled through an inverter to the grid and feed in power that synchronizes with the conventional power in the grid. The grid connected solar power operates at 240 V and at 50 Hz frequency through inverter systems.

1.3 Objectives

The objectives of this project are;

1. To design single phase inverter connected to photovoltaic (PV) for tackling the integration issue.

2. To evaluate the performance of single-phase inverter connected to grid with maximum power point tracking controller in terms of regulated voltage and current.

1.4 Scope of Study

Grid-connected PV System comprises of PV panel, a DC/AC converter that capably connected to the grid. This system is used for power generation in places or sites accessed by the electric utility grid. If the PV system AC power is greater than the owner's needs, the inverter sends the surplus to the utility grid for use by others. The utility provides AC power to the owner at night and during times when the owner's requirements exceed the capability of the PV system. Depending on the application and requirements PV system can either be a stand-alone or hybrid system. So, the scope of this project is consisting by follow steps.

- Conduct a literature survey of the PV system technologies consisting of solar array, grid, power converter, MPPT charge controller, PI controller and inverter.
- Model the various parameters of grid connected PV system in MATLAB SIMULANK.
- Simulate the system to analyse its performance related to the output characteristics of the model
- Analyze the impact of grid connected PV system relating to power quality issues.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter based on the discussion related to research work which had been done in the past and also it compares with findings. This chapter also evaluates the improvements of previous research which compared with the new research It also focuses on design single-phase inverter connected to grid using MATLAB. A PV system developed with ability to emulate dynamic ecological conditions. The PV system is designed using MATLAB/Simulink® software.

According to several researcher's [6],[7]and studies on the features of PV module, the radiation on solar panel can only convert it around 20-30% of efficiency to electrical energy. In order that conquer power loss of solar panels, a MPPT algorithm is required indeed. Dealing on this several studies have been made and proposed on various methods

2.2 Overview

Photovoltaic energy showed significant improvement in the power system's emission reduction, reliability, efficiency, and security [1, 2]. Energy generation aspects are to make the individual houses, offices and societies self-sufficient in terms of energy by distributed generation. One of the most relevant areas of distributed generation deals with the photovoltaic (PV) power generating systems connected to grid.

In the literature, several works focused on the power control of grid-connected photovoltaic generators [3]. However, they generally concentrated on three-phase grids. For single-phase grid- connected systems, researchers have developed power control strategies, which imitate the concept of decoupled active and reactive power control of three-phase converters, realized in the synchronous reference frame

[4]. Voltage oriented control (VOC) is the most used strategy for active and reactive powers control [5]. In fact, the ac current is decoupled into direct and quadrature power components. These current components are then regulated in order to eliminate the error between the reference and measured values of the active and reactive powers [6]. In most cases, the active power current component Id, is regulated through a dc-link voltage control aiming at balancing the active power flow in the system [7]. The comparison of the reference and measured currents allows the converter proper switching states to be generated, the current error to be eliminated and the desired ac current waveform to be produced.

In recent years, the single-phase grid-connected photovoltaic (PV) systems have growth rapidly in commercial and residential section [1]. Particularly, the single-phase inverter applications have high penetration due to high reliability, high efficiency, and low cost [2]. Traditionally, the conventional single-phase grid-connected PV inverters can divide two isolation transformer applications. An inverter with a high-frequency transformer has a DC-DC converter to increase the DC input voltage, and the inverter with a line-frequency transformer can separate PV panels from grid [3]. However, the existence of isolation transformers in the system that decrease the system efficiency, and can increase the system size, complexity, and cost [4]. The PV industry is present everywhere, but there is a clear concentration in industrialized countries. As part of its energy strategy and see its high dependence on the outside for energy supplies, Morocco gives priority to sustainable development and renewable energy especially photovoltaic.

Grid-connected single-phase photovoltaic (PV) systems are nowadays recognized for their contribution to clean power generation. A primary goal of these systems is to increase the energy injected to the grid by keeping track of the maximum power point (MPP) of the panel, by reducing the switching frequency, and by providing high reliability. In addition, the cost of the power converter is also becoming a decisive actor, as the price of the PV panels is being decreased [1]. This has given rise to a big diversity of innovative converter configurations for interfacing the PV modules with the grid. Currently, the state-of-the-art technology is the two- level multi string converter. This converter consists of several PV strings that are connected with dc – dc converters to a common dc – ac converter [2], [3]. This topology features several advantages such as the independent tracking of the MPP of each string to the existing plant. This converter topology can reach peak efficiencies up to 96% [4]. In the last years, multilevel converter topologies have been also considered in PV applications [5]. These converter topologies can generate high-quality voltage waveforms with power semiconductor switches operating at a frequency near the fundamental [6]. Although, in low-power applications, the switching frequency of the power switches is not restricted, a low switching frequency can increase the efficiency of the converter [7]. Additionally, multilevel converters feature several dc links, making possible the independent voltage control and the tracking of the MPP in each string. This characteristic can increase the efficiency of the PV system in case of mismatch in the strings, due to unequal solar radiation, aging of the PV panels, and different type of the cells or accumulation of dust in the surface of the panels [8]. And the possibility to scale the system by plugging more strings. Traditional multilevel inverters include cascaded H-bridge inverter, diode clamped inverter, and flying capacitors inverter.

This paper focuses on the single-phase 11-level (5 H bridges) cascade multilevel inverter. Multilevel inverter structures have been developed to overcome shortcomings in solid-state switching device ratings so that they can be applied to high-voltage electrical systems. The multilevel voltage source inverters' unique structure allows them to reach high voltages with low harmonics without the use of transformers. This makes these unique power electronics topologies suitable for flexible ac transmission systems (FACTS) and custom power applications [6, 7]. The use of a multilevel converter to control the frequency, voltage output (including phase angle), and real and reactive power flow at a dc/ac interface provides significant opportunities in the control of distributed power systems. The general function of the multilevel inverter is to synthesize a desired ac voltage from several levels of dc voltages. For this reason, multilevel inverters are ideal for connecting either in series or in parallel an ac grid with renewable energy sources such as photo-voltaic or fuel cells or with energy storage devices such as capacitors or batteries. Additional applications of multilevel converters include such uses as medium voltage adjustable speed motor drives, static var compensation, dynamic voltage restoration, harmonic filtering, or for a high voltage dc back-to-back intertie. Because distributed power sources are expected to become increasingly prevalent in the near future, the use of a multilevel converter to control the frequency and voltage output (including phase angle) from renewable energy sources will provide significant advantages because of its fast response and autonomous control.

Additionally, multilevel converters can also control the real and reactive power flow from a utility connected renewable energy source. These power electronic topologies are attractive for continuous control of system dynamic behaviour and to reduce power quality problems such as voltage harmonics, voltage imbalance, or sags [8-10] With a capacitance connected in parallel with the renewable energy source, a multilevel converter can provide static var compensation even when there is no output power from the photovoltaic or fuel cell energy source. With banks of batteries or large capacitors on the dc bus, the multilevel converter can provide significant ride through capability for voltage sags or load swings experienced at the utility interface connection.

2.3 Review on photovoltaic

A photovoltaic cell which is also called as photoelectric cell is a semiconductor (silicon alloys and other materials) device that responsible of converting light to electrical energy. This impact is called by photovoltaic effect. The process of photovoltaic effect starts when the photons of light is greater than the band gap between N-type silicon channel and P-type silicon channel. In result the electron changes the position caused the flow of current. Meanwhile a photovoltaic cell is different from a photodiode because in a photodiode, the light falls on n channel of the semiconductor junction and gets converted into current or voltage signal whereas in photovoltaic cell, it always forwards biased as shown in figure 2-1 [2].

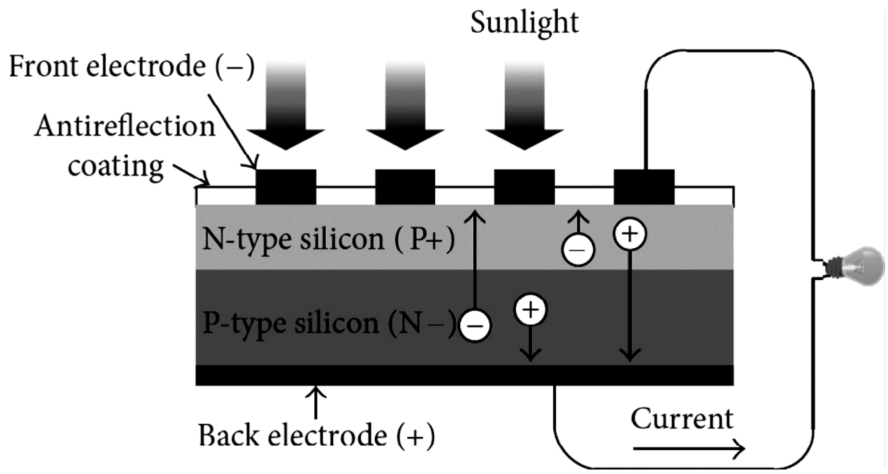

Figure 2-1 Solar Panel working principle [2]

Crystal silicon is one of the important semiconductor materials that being used to make a solar cell. There are special properties of silicon material, where it has a specific molecular structure. There is a process of doping is used to combine other element with the crystal silicon to achieve a negative or positive charge. This process is carried out because pure crystal silicon is almost neutrally charged, so it would not function well to produce electricity [2].

2.3.1 PV Models

The foundational power conversion unit of a PV system is the solar cell. Over the past decades, all solar manufacturing companies adapted in silicon material for manufacturing PV cells, even though other materials have been developed. Progresses in manufacture of solar cells are moving so swiftly, for the cells can be classified single crystalline, Polycrystalline and thin film.

The power that produced by a single solar cell is not enough for general use since it produces an output voltage less than 1V; cells must be connected in series-parallel configurations to produce enough power for high-power applications. They are usually set up into modules. However, there are various sizes of PV modules commercially available in the market; the most commonly used module is 36 to 72 solar cells connected in series to produce enough voltage. For higher power requirement, the modules are interconnected in series/parallel to form array as shown in Figure 2.2.

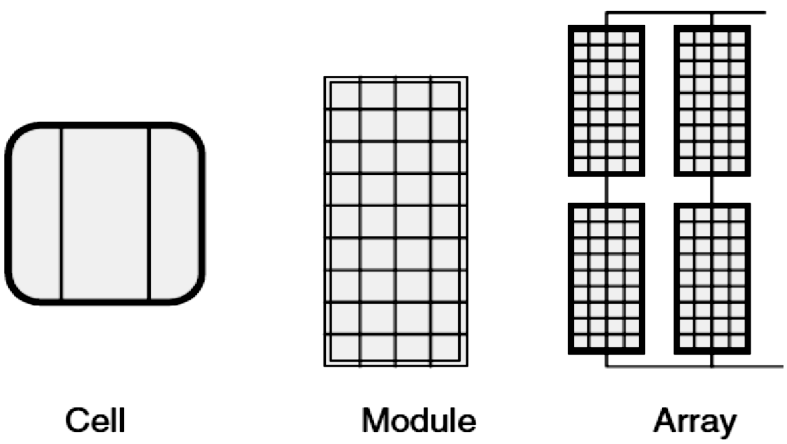

Figure 2-2 Photovoltaic cells, modules, and arrays [6].

2.3.2 Characteristics of the Photovoltaic Array

The characteristics of photovoltaic based on I-V and P-V having different irradiation with respect to temperature. The most power available has been achieved at the maximum power point (MPP) below the limits of sunlight as well as at the temperature. The I-V characteristics represents the labels of maximum power point (MPP) based on PV module is shown in Figure 2.3.

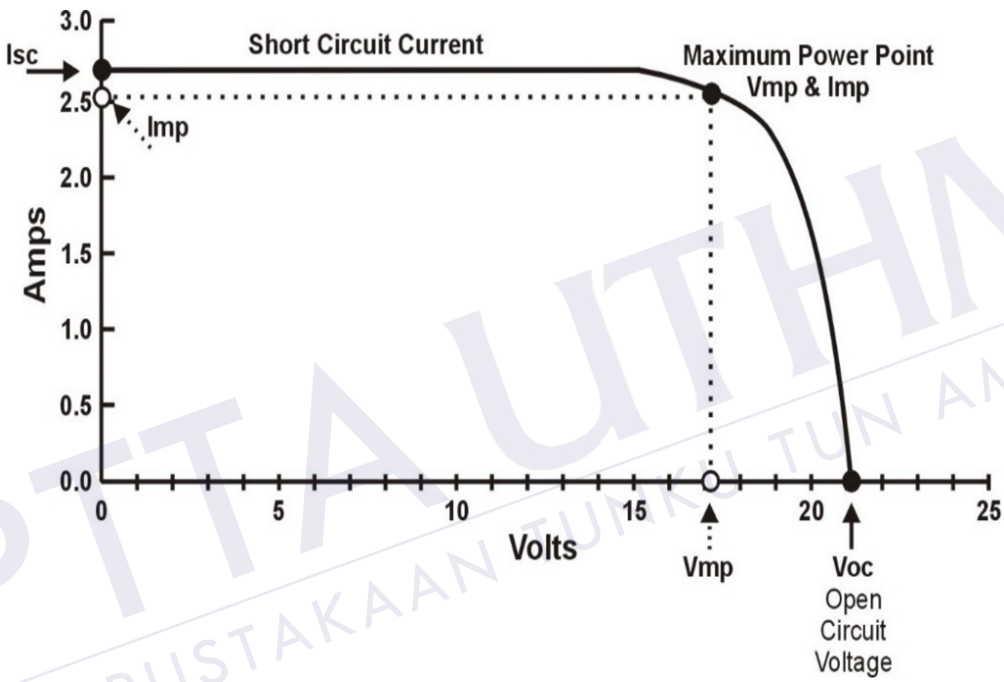

Figure 2-3 sample I-V curve [7].

2.3.3 Effect of irradiance and temperature

Cloudy weather is the main cause of getting less efficiency from the solar panels because as the irradiance of solar panels is getting decrease the production of power will be decrease. Hence the current keeps lower due to the less radiation of sun light strike on the panels. PV module characteristics having different irradiation based on various MPP is shown in Figure 2.4.

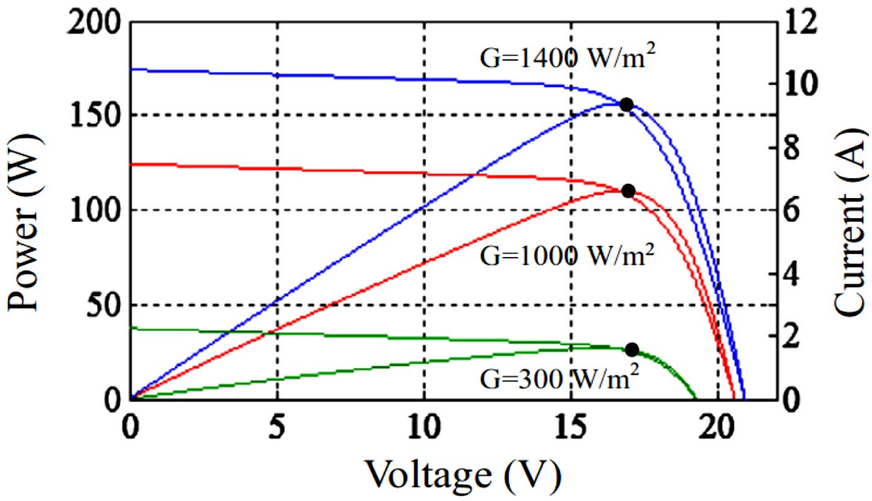

Figure 2-4 Different irradiation curves in PV modules [2]

Meanwhile the flow of efficiency of power should not stopped, mainly the rising of current in PV panels is not caused of decreasing the production of power created using source of panels in fact the voltage drops is the main reason which inefficient to the system. It is better to use the ventilation for solar panels which provide controlling the atmospheric temperature to the system. Characteristics of PV module based on various alternations regarding the atmospheric temperature is shown in Figure 2.5 [2].

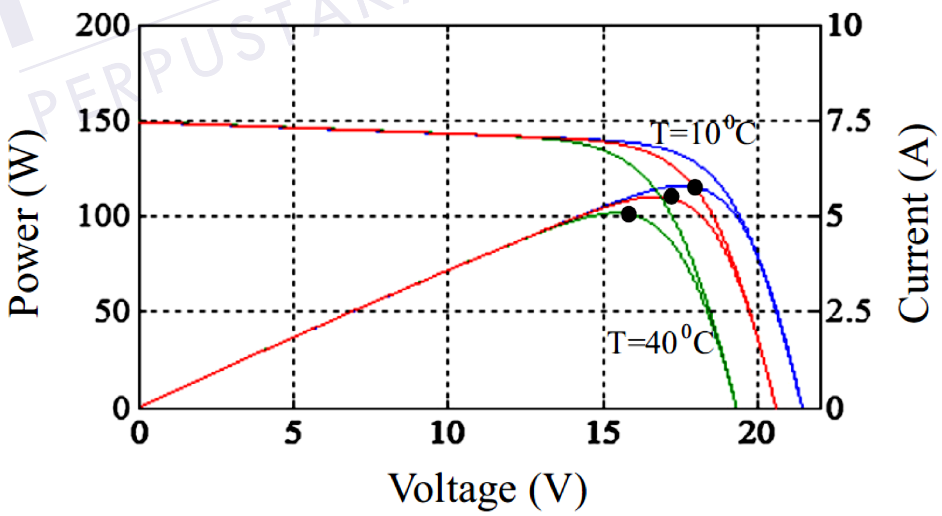

Figure 2-5 Different temperature I-V curves in PV modules [3].

Moreover, the PV modules are dealing with shading effect, the shading effect are the cause of reducing performance of solar panels called shading conditions.

The shading condition is analyzed when it seen more than a peak that gives various curves which differentiate and compared with condition of ideal PV module based on I-V and P-V curves based on partial condition. These curves measure the total power which makes links to the maximum power point and this will be the local maximum point is shown in Figure 2.6.

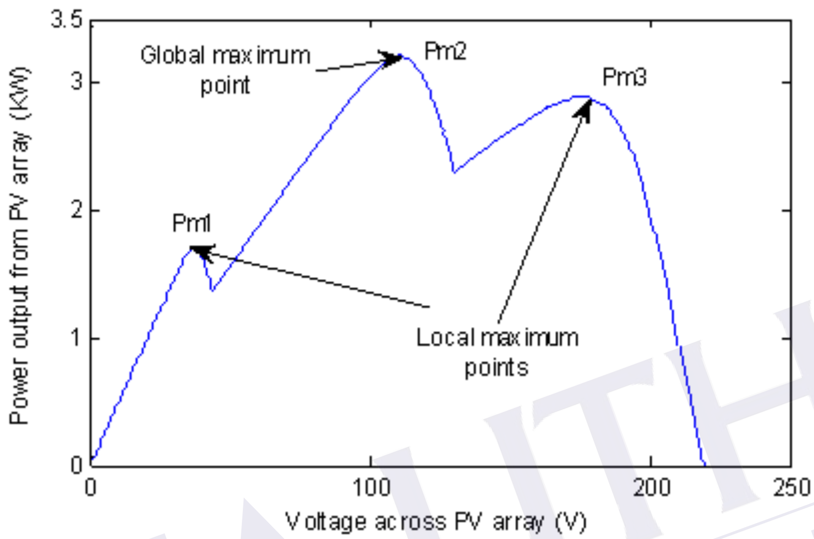

Figure 2-6 I-V and P-V curve under partial shading condition[4]

2.4 DC/DC Converter

DC-DC converters have huge applications in telecommunication, digital applications, software industry, and in the industrial applications. The output voltage after applying these converters may be high or low or equal to the supply depending on the type of the converters used.

For the boost converters the output voltage is greater than the input voltage which is required for the special type of applications. The basic boost converter consists of an inductor (L), power electronic switch, unidirectional diode, capacitor (Cl). The Duty cycle to the power electronic circuit can be varied using some specially designed firing circuit. Here we will give the firing to the converter using maximum power point tracking technique, which will drive the converter at its maximum power point operation.

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